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IMPROVED EQUATIONS FOR PREDICTING SKEIN STRENGTH OF CARDED YARN, WITH SPECIAL REFERENCE TO CURRENT COMMERCIAL PRODUCTION OF AMERICAN COTTON

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SUMMARY AND CONCLUSIONS

This report presents two new count-strength-product equations for predicting skein strength of carded warp singles yarn of any size over a wide range with special reference to current commercial production of American cotton. The new equations are better adapted for predicting strength of yarn processed from the general run of American upland cottons in current commercial production than are similar count-strength-product equations published previously by the Cotton Division of the U. S. Department of Agriculture.

A random check of comparative prediction values of yarn strength for some later commercial cottons (crop years 1951, 1952, and 1953) has shown the prediction values obtained by the new equations to be, on the average, 5 to 10 percent closer to actual values than those obtained by the former equations. Moreover, the precision of yarn-strength predictions furnished by the new equations is approximately the same for early season, midseason, or late-season harvested cottons. This was not the case with the former equations.

One of the two new equations reported here includes six factors of raw-cotton quality: Grade index, upper half mean length, length uniformity ratio, fiber fineness (weight per inch), fiber strength, and percentage of mature fibers (standard method). The other equation contains the three most important fiber properties to yarn strength; namely, upper half mean length, fiber strength, and fiber fineness.

The new equations were developed from data representing a total of 842 commercial cottons, grown in approximately 100 selected cotton improvement groups across the U. S. Cotton Belt, for the 3 crop years of 1948, 1949, and 1950. A total of 3,267 lots of yarn, ranging in sizes from 14s to 60s, was used in the analyses. All yarns were of a warp type of construction and possessed a semihard twist. The principal varieties of cotton grown in current commercial production were included in this study. All cottons were grown, harvested, and ginned under commercial conditions identified with their respective growth areas. Three lots of cotton representing early, midseason, and late-season samples were obtained from each growth locality.

The degree of multiple relationships existing between the factors of raw-cotton quality and count-strength product in the two equations here presented are shown by the statistical values listed. The results obtained from using, as independent variables, the 3 most important fiber properties to count-strength product are almost as good as those with all 6 cotton-quality factors, the coefficient of correlation ($\bar{R}$) being 0.896 in the case of the 3 factors and 0.907 when the 6 factors are used. The correlation values obtained with this large series of commercial cottons grown over wide areas across the U. S. Cotton Belt are not as good as some previous ones obtained with cottons from certain experiment station annual variety test series.

The standard error of prediction ($\overline{S}$) of count-strength product or yarn strength is almost as good for the 3 fiber-property equation as for the 6 quality-factor equation. It is ± 165 csp units or 7.3 percent for the former and ± 156 csp units or 6.9 percent for the latter. These figures indicate the range within which, on the average, two-thirds of the actual values of count-strength product or yarn strength would be expected to occur in relation to the predicted values.

The average net contribution of the respective factors to count-strength product of all yarn sizes collectively for the 842 cottons from the 1948-50 crop years are shown by the beta coefficients and by the percentage values listed. The three most important fiber properties in this respect, listed in order of their contribution, were as follows: upper half mean length, fiber strength, and fiber fineness. Length uniformity ratio, grade index, and percentage of mature fibers caused relatively small measurable effects on count-strength product.

An illustration of the calculations necessary for predicting skein strength of any size of yarn is shown for one of the count-strength-product equations. For the same accuracy of sampling, fiber measurements, yarn tests, and general range of cotton quality, the level of yarn-strength predictions derived by use of the equations reported here may be expected to vary somewhat from the actual yarn-strength values obtained for other cottons, as influenced by the processing organization, the yarn construction, and the yarn-twist multiplier used.

After several trial determinations, if the yarn-strength predictions obtained by use of one of the equations presented in this report differ more or less consistently from actual yarn-strength values, the future prediction values can be adjusted to the level of fiber tests, textile processing, yarn structure, and yarn twist by increasing or decreasing them by whatever percentage found necessary. This procedure gives needed flexibility to the application of such prediction equations and, in turn, enables the prediction values so obtained to possess more practical meaning and significance under diverse conditions than otherwise would be possible.

IMPROVED EQUATIONS FOR PREDICTING SKEIN STRENGTH OF CARDED YARN WITH SPECIAL REFERENCE TO CURRENT COMMERCIAL PRODUCTION OF AMERICAN COTTON

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INTRODUCTION

Equations for predicting yarn strength on the basis of measurable fiber properties and other factors of quality representing various kinds of cotton are the subject of continuing studies by the Cotton Division of the Agricultural Marketing Service. Such equations and related information derived from these studies are helpful to the cotton trade and textile industry in choosing cottons best suited to the manufacture of specific products and for meeting various levels of product quality.

From this series of relationship studies on cotton fiber properties, 18 previous reports (8 through 25) 1/ were published. The broad problems and objectives underlying these studies, as well as the benefits expected from the development and application of such information, were discussed in a report issued by the Department of Agriculture in 1947 (7).

Two count-strength-product equations for use in predicting skein strength of any size of carded warp singles yarn on the basis of measured fiber properties identified with American upland cotton were published in reports (8) and (18). One of those equations included 6 factors of raw-cotton quality and the other, the 3 most important fiber properties to yarn strength (fiber length, fiber strength, and fiber fineness). Those predicting equations were developed from data representing 828 lots of cotton grown in experiment station annual variety test series and in selected cotton improvement groups during the 3 crop years of 1945, 1946, and 1947.

When applying those equations to commercial American cottons representing current varieties, growth conditions, and various dates of harvesting as well as prevailing harvesting methods and ginning conditions, it was found that the predicted values of yarn strength generally exceeded the actual yarn-strength values obtained, and in many cases, the disparities were unduly large. More particularly, it was observed that the predicted values generally exceeded the actual values to a larger degree in the case of midseason cottons as compared with early

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1/ Underscored numbers in parentheses refer to Literature Cited p. 15.

season cottons, and the predicted values generally exceeded the actual values to a greater degree for late season cottons than for midseason cottons. Interest, therefore, centers in the cause or causes for such differences between predicted and actual yarn-strength values as related to date of harvesting, and in the development of predicting equations that are better adapted to current commercial production of American cotton representing the entire harvesting season.

Examining the data which served as the basis for the count-strength-product equations previously published, several conditions were present which probably caused the elevated bias in yarn-strength predictions observed in connection with more recent commercial cottons representing various dates of harvesting. In the first place, 584 of the total 828 cottons involved in the 1945-47 series, or 70 percent of them, were obtained from the experiment station annual variety test series and, thereby, represented better than average commercial growth conditions, care of cultivation, and method of harvesting. A number of those samples also represented special varieties, strains, and selections that never reached commercial production for agronomic or other reasons. Thus, only 30 percent of the cottons in that series may be said to have represented commercial cottons in the generally accepted sense.

Moreover, 90 percent of the cottons with which the previous count-strength-product equations were identified represented early season picking; only 10 percent of them represented midseason picking; and no late-season samples were included. The effects of all of the foregoing factors considered collectively would seem to offer sufficient explanation for the relatively high predictions of yarn strength that generally were obtained when the former count-strength-product equations were applied to current American cottons in commercial production, and for the increasing disparities observed with midseason and late-season cottons over those with early harvested samples.

In an effort to provide count-strength-product equations capable of furnishing better predictions of yarn strength for current American cottons in commercial production than can be done by such equations as are now available, two new equations have been developed. The new predicting equations, together with their expected precision of yarn-strength estimates and other evaluations of the relationships embraced by the two equations, are presented in this report. Practical use of one of the equations is illustrated in workable detail.

SAMPLES, TESTS AND DATA

The fiber, spinning, and yarn-strength tests on the cottons used in these analyses were made in the laboratories of the Cotton Division, Agricultural Marketing Service, at Clemson, S. C., and at College Station, Tex.

The fiber and yarn-strength data which served as the basis of this study are contained in publications (3), (4), and (5).

Cottons. All cottons were of the American upland type and they were grown commercially in selected cotton improvement groups across the U. S. Cotton Belt, within their general area of growth adapation, for the 3 crop years of 1948 through 1950. Each variety and location of growth were represented by early season, midseason, and late-season samples. The cottons also represented hand picked and mechanical methods of harvesting, and they were ginned on commercial saw gins serving the respective cottom improvement groups.

Sampling. Classing samples weighing 4 to 6 ounces were assembled for the most frequently occurring grade and staple-length groups of each selected cotton improvement area, until 8 to 10 pounds of raw cotton had been accumulated.

The original grade and staple length designations, which served as the basis for selecting and compositing the comparable lots of cotton for test purposes, were those assigned to the individual samples of raw cotton by cotton specialists of the U. S. Department of Agriculture. Classification of the samples was made in accordance with official standards for staple length and grade, as described for American upland cotton in the publication entitled "The Classification of Cotton" (2).

As a result of the method used for selecting the samples, not all of the range of grades and staple lengths appearing in each cotton improvement area was represented by the test cottons.

Processing. Details as to the processing procedure by which the cottons were converted into yarns may be found in the reports setting forth the fiber and spinning test results (3), (4), and (5). Report (6) describes the service testing of cotton by the Cotton Division, including not only processing procedures and waste analyses but also fiber, yarn and fabric tests.

In brief, all the cottons used in this study were processed through the picker and card by the same standard procedure, and with the same settings and speeds. The cottons for the 2 crop years of 1948 and 1949 were processed at one rate of card production which was 9-1/2 pounds per hour; those for 1950 were carded at one of 3 different rates of production, depending upon the length of the individual cotton. Cottons of 15/16 inch and shorter in staple length were carded at 12-1/2 pounds per hour; those from 31/32 inch through 1-1/16 inches were carded at 9-1/2 pounds per hour; and those from 1-3/32 inches through 1-1/4 inches were carded at 6-1/2 pounds per hour.

The fact that a small proportion of the cottons were carded at somewhat different rates of production did not influence the statistical values obtained from the correlation analyses to any appreciable degree. As shown in report (23), it was found that different rates of card production, ranging even from 2.0 to 15.5 pounds per hour, did not cause the strength of various sizes of carded yarn to vary with any statistical significance.

All yarns from all cottons were processed from long-draft roving by long-draft spinning equipment; they represented a warp-type of construction, and possessed a semihard twist. The twist multipliers varied with the upper half mean length of the cottons, the one selected for each cotton being that which gave approximately the maximum yarn strength for an average or typical cotton of the particular classified length. The twist multiplier used in each case, therefore, was not selected to compensate for the influence of other fiber properties involved but represented an empirical selection.

Fiber properties. Six elements of raw-cotton quality were used as independent variables in this study, as follows:

Upper half mean length, in inches, as determined by the Fibrograph method.

Length uniformity ratio, index, as determined by the Fibrograph.

Fiber fineness, in micrograms per inch, as evaluated by the Micronaire method.

Fiber strength, in terms of 1,000 pounds per square inch, as determined by the Pressley tester.

Percentage of mature fibers, as classified and counted on the basis of 2-to-1 lumen to wall ratio, after they had been permitted to swell in an 18-percent sodium hydroxide solution.

Grade of cotton, expressed as an index.

Grade index was used in this study, as explained in the report of this series having to do with the strength of 22s yarn, regular draft (16). The conversion chart for obtaining grade index values of samples of raw cotton, corresponding to various grade designations originally assigned, was shown in previous reports of this series.

The fiber tests relating to the data used in these analyses were those described in the publication entitled "Cotton Testing Service" (6) and covered more in detail by ASTM Standards on Textile Materials (1).

All fiber tests were made under controlled atmospheric conditions with a temperature of 70°F. ± 2° and a relative humidity of 65 percent ± 2 percent according to ASTM specifications (1).

Yarn size. Yarn size, expressed in terms of the generally used or so-called English yarn numbers for cotton, was included as the seventh independent variable in the multiple correlation analyses, when count-strength product of various yarn sizes was used as the dependent variable.

For the 1948 cotton, 4 sizes of yarn were spun from each sample. All the cottons were spun into 14s, 22s, and 36s yarn. The finest yarn spun from each cotton was either 60s, 50s, or 44s, depending upon the respective staple lengths of the cottons. Data representing all yarn sizes processed from all cottons were used in the analyses.

For the 1949 cottons, all samples were spun into 14s, 22s, 36s, and 50s yarn. Data representing all yarn sizes processed from all cottons were used in the analyses.

For the 1950 cottons, either 3 or 4 sizes of yarn were spun from each cotton. All the cottons were processed into 22s and 36s yarn. The finest yarn spun from each sample was either 50s or 36s, and the coarsest yarn processed from each sample was either 22s or 14s, depending upon the respective staple lengths of the cottons. Data representing all yarn sizes processed from all cottons were used in the analyses.

Yarn strength. Conventional skein-strength tests of all yarns were made according to the generally adopted procedure described in ASTM Standards on Textile Materials (1) and referred to in Cotton Testing Service (6), and expressed in terms of pounds.

Values for count-strength product were obtained by multiplying the individual yarn strengths by their respective yarn sizes, and expressing the results in terms of count-strength-product units.

All yarn-strength tests were made under the same controlled atmospheric conditions, as specified by ASTM for fiber and yarn testing, namely, a temperature of 70°F. ± 2° and a relative humidity of 65 percent ± 2 percent.

STATISTICAL ANALYSES

This report covers results obtained from multiple correlation analyses, representing a total of 842 cottons and 3,267 lots of yarn, ranging in size from 14s to 60s, crop years 1948-50. Using 6 elements of raw-cotton quality, as previously referred to, and using the 3 most important fiber properties to yarn strength, 2 multiple correlation analyses were made with count-strength product of all yarn sizes spun from all cottons.

The nature and scope of the data which served as the basis of these correlation analyses are indicated by the values shown in table 1.

Table 1.--Comparison of statistical values, representing data identified with the independent and dependent variables used in multiple correlation analyses, for cottons from selected cotton improvement groups, 3 crop years 1948-50

Factors used in analysis, as--	Value for--					
	Observations 1/	Mean	Standard deviation	Maximum	Minimum	Range
	Number					
Independent variables:						
Grade of cotton..................index	842	97.60	± 5.07	105.	75	30.
Upper half mean length.............inch	842	1.06	± .07	1.28	.83	.45
Length uniformity ratio...........index	842	78.60	± 2.21	93.	70.	23.
Fiber fineness (wt./in.)......microgram	842	4.29	± .51	5.9	2.5	3.4
Fiber strength....1,000 lb. per sq. in.	842	78.35	± 6.22	98.	60.	38.
Mature fibers (standard method) percent	842	81.17	± 5.66	94.	50.	44.
Yarn size.......................number	3,267	31.10	± 14.63	60.	14.	46.
Dependent variable:						
Count-strength product..............csp	3,267	2,264.93	± 372.41	3,598.	1,200.	2,398.

1/ Values shown indicate the number of observations used in each correlation analysis.

The same general pattern of statistical analyses was followed in this study as that followed in all previous studies of this series. For more detailed information with regard to the statistical terms, measures, and techniques applied, see appendixes and literature citations in the first and third reports (10), (12).

Beta coefficients and percentage values calculated from them were used to evaluate the relative net contribution or importance of the fiber properties to count-strength product, instead of partial correlation coefficients as was done in the early studies of this series. The reason for the change in method was explained in report (16).

All statistical values reported herein are so-called corrected ones, as obtained from multiple linear correlation analyses. No curvilinear correlation analyses were made in this instance because of the general ranges of cotton quality factors involved in this study and because previous curvilinear analyses in this series of studies have given no better results with yarn strength than did linear correlation analyses.

EQUATIONS FOR PREDICTING SKEIN STRENGTH OF CARDED YARN OF ANY SIZE ON THE BASIS OF RAW-COTTON QUALITY MEASUREMENTS AND YARN SIZE

The equations for predicting skein strength of cotton yarns on the basis of certain elements of raw-cotton quality, as covered in this report, refer to carded warp yarns, processed on long draft equipment, and possessing a semi-hard twist. No analyses have been made with single-strand strength of yarns and no analyses have been included for yarns processed on regular-draft equipment.

The yarn-strength predictions obtained for other cottons by use of the equations and procedures recommended in this report should be relatively accurate, as expressed in terms of the fiber tests, textile processing, and yarn structure used in the laboratories of the Cotton Division, Agricultural Marketing Service. For the same accuracy of sampling, fiber measurements, and yarn tests, however, the level of yarn-strength predictions derived by use of the equations reported here may be expected to vary somewhat from the actual yarn-strength values obtained by others from other cottons, as influenced by the textile-processing organization used and by the amount of twist in the yarns.

After several trial determinations, however, if one finds that the yarn-strength predictions obtained by use of the equations presented in this report consistently differ from his actual yarn-strength values, he can adjust his future predictions to his level of fiber tests, textile processing, yarn structure, and yarn twist by increasing or decreasing them by whatever percentage he finds to be necessary. Obviously, it would be impractical to develop such equations for predicting yarn strength that would represent each and every one of the many processing organizations and yarn structures available in the textile industry.

But, by following the procedure of adjustment of yarn-strength predictions suggested above, more flexibility is given to the available equations than otherwise would be possible, and the individual needs of different cotton spinners are better served in maintaining quality control and meeting specifications of manufactured products. Thus, the two equations reported here can be so used in a manner by supplemental procedure as to serve satisfactorily most practical problems and purposes connected with skein strength of carded cotton yarn, and more particularly carded warp yarn.

Prediction of yarn-strength by count-strength-product equations. The equation for predicting directly the skein strength of any size of carded singles yarn from 10s to 60s on the basis of 6 elements of raw-cotton quality, as adapted more particularly to current commercial production of American upland cotton, represents 842 selected commercial cottons covering a wide range of quality and 3,267 lots of yarn extending from 14s to 60s, crop years 1948 through 1950. That equation is listed as follows:

$$X'_{91} = -2{,}939.560 - 17.636X_{41} + 6.319X_{88} + 2{,}126.624X_{17} + 19.416X_{19}$$

$$- 131.902X_{104} + 3.526X_{35} + 20.889X_{33}$$

Where X'_{91} = estimated count-strength product, in csp units

X_{41} = size of yarn, as yarn number

X_{88} = grade of cotton, as an index

X_{17} = upper half mean length, in inches

X_{19} = uniformity ratio, as an index

X_{104} = fiber weight per inch, in micrograms

X_{35} = percentage of mature fibers

X_{33} = fiber strength (Pressley), in 1,000 lb. per sq. in.

By using the three most important fiber properties, as revealed by the beta coefficients derived from the analysis of the data from which the above equation was derived, the following equation was developed:

$$X'_{91} = -1{,}303.504 - 17.590X_{41} + 2{,}428.474X_{17} - 59.786X_{104} + 22.964X_{33}$$

As may be noted from the symbols previously defined, the four independent variables used in the above equation are yarn size, upper half mean length, fiber fineness (weight per inch), and fiber strength. The three variables omitted in this instance are percentage of mature fibers, uniformity ratio, and grade.

The standard error of prediction of count-strength product with the equation using 6 cotton quality factors is ± 156.56 csp units or 6.91 percent, the latter of which is based on the mean count-strength product for the 3,267 lots of yarn representing the entire series of 842 cottons. The corresponding standard error of prediction by the 3 most important fiber properties to count-strength product is ± 165.61 csp units or 7.31 percent. Thus, the difference between the two standard errors of prediction identified with those two equations is only ± 9.05 csp units or 0.40 percent. For all practical purposes, this is a relatively small and negligible difference.

On the basis of the standard errors of prediction referred to above and other statistical values presented later in this paper, it is evident that the equation including the 3 most important fiber properties should give practically as reliable predictions of count-strength product or yarn strength of various sizes as the equation including all 6 cotton-quality factors. This is a matter of considerable importance from the standpoint of required laboratory work and statistical calculations, and causes a saving of the time and expense necessary for making the rather slow and laborious test for fiber maturity.

Comparative precision of yarn-strength predictions identified with count-strength-product and individual yarn-size equations. As discussed in report (18), one of the principal objectives of that study was to develop an all-purpose equation rather than equations for specific sizes of yarn, such as 22s and 50s. With equations for individual yarn sizes, subsequent and supplemental use of a conversion formula also is required in order to obtain predictions of strength of sizes of yarn other than that for which the equation was developed.

The comparative predictions and differences shown in report (18) indicate that the count-strength-product equation gives practically the same precision of prediction as do the equations for specific yarn sizes used either separately or in conjunction with a conversion formula. A tendency, however, is noticed for the latter method to yield yarn-strength estimates slightly more accurate. But, on an average, the standard error is only ± 0.23 pound more for the count-strength-product equation than for the equations developed for 22s and 50s yarn, used either separately or in conjunction with the conversion formula. For 14s yarn, the standard error with the count-strength-product equation is ± 0.40 pound more; for 22s, ± 0.07 pound more; for 36s, ± 0.10 pound more; for 44s, ± 0.54 pound more; for 50s, ± 0.26 pound more; and for 60s, there is no difference. Such small disparities, for all practical purposes, may be disregarded.

Thus, on the basis of the comparative statistical values cited above, it is apparent that there is a very close agreement in the results by the two methods of calculating yarn-strength predictions. However, by the count-strength-product method, only one equation is necessary for any size of yarn over a wide range; by the strength equations for specific sizes of yarn, two or more equations are necessary as well as a conversion formula. For broad and practical purposes, therefore, a count-strength-product equation possesses distinct advantages over several individual yarn-size equations for predicting the strength of various sizes of yarn.

Meaning of values in predicting equations. The equations reveal the mathematical evaluation of the multiple relationships existing, on the average, between the measures of various factors used in the respective analyses. The values that go to make up a particular equation are relative throughout and comparative within themselves. The values for the respective regression coefficients, however, are not strictly comparable from equation to equation because of the fact that the level of the regression values in each equation is identified with the value shown for the constant factor of each equation, and those values differ appreciably in various equations.

Pertinent information bearing on the multiple relationships occurring between the variables considered in the respective analyses may be obtained from the regression equations. This is possible because respective regression coefficients in such equations serve to indicate directly the amount of change in a particular dependent variable caused, on the average, by one unit increase in each independent variable. The sign attached to a regression coefficient signifies whether a unit increase in the value of an independent variable produces an increase or decrease in the scale of values for the dependent variable.

In examining and comparing the values of the regression coefficients listed in the two equations presented, it should be remembered that different units of measurement necessarily had to be used for the various independent variables included in the statistical analyses, as shown in the following tabulation:

Independent variables	Unit of measurement
Grade of cotton	1 index unit
Upper half mean length	1 inch
Length uniformity ratio	1 index unit
Fiber fineness	1 microgram per inch
Percentage of mature fibers	1 percent
Fiber strength	1,000 lb. per sq. in.
Yarn size	1 yarn number

As shown above, the unit of measurement for upper half mean length is 1 inch. Therefore, if the effect of upper half mean length on a dependent variable is desired in terms of the more conventional units of 1/32-inch, as generally used in the cotton trade and textile industry, the regression coefficients shown in equations for the length factor should be divided by 32. No further calculations or adjustment, however, are needed in connection with any of the other regression coefficients.

In this connection, it should be emphasized that, when a predicting equation is said to represent the average relations of cotton fiber properties to count-strength product, yarn strength, yarn appearance or number of neps per unit of area in card web, it does not precisely possess that meaning. Rather, such an equation represents the average relations of the measures used for the respective fiber properties to the measure used for the dependent variable. There is an important distinction between those two concepts. Thus, when varying numbers and combinations of factors are used in correlation analyses, when different or alternative measures are included as respective independent and dependent variables, and when different series of cottons vary appreciably in their ranges and distributions of fiber properties, fluctuations in predicting equations and associated statistical values occur and never can be avoided. Inconsistency in such findings, therefore, is consistency under those conditions.

ILLUSTRATION OF CALCULATIONS NECESSARY FOR PREDICTING YARN STRENGTH

The method of predicting yarn strength by one of the two over-all count-strength-product equations developed from 3,267 lots of yarn representing 842 cottons, crop year 1948-50, is described below. The fiber data used in this example represent the first cotton listed in that series.

Calculations are illustrated in this instance for predicting the strength of 4 sizes of carded warp singles yarn, namely, 14s, 22s, 36s, and 60s. Predictions of strength for any size of yarn, however, may be obtained by the same procedure, except care must be exercised to multiply the factor of - 17.636 in the case of the 6-fiber property equation, or - 17.590 in the 3-fiber property equation, by the particular size of yarn in question.

The equation used in the example cited includes 6 elements of cotton quality and yarn size, as follows:

$$X_{91}^{\beta} = -2{,}939.56 + 6.32X_{88} + 2{,}126.62X_{17} + 19.42X_{19} - 131.90X_{104}$$
$$+ 3.53X_{35} + 20.89X_{33} - 17.64X_{41}$$

where X_{91}^{β} = predicted yarn strength

Substitutions are made in the equation, as follows:

X_{88} = 104, grade index corresponding to Strict Middling

X_{17} = 1.08, upper half mean length, in inches

X_{19} = 80, uniformity ratio, as an index

X_{104} = 3.9 fineness of fiber, in micrograms per inch

X_{35} = 84, percentage of mature fibers

X_{33} = 94, tensile strength of the fibers, in terms of 1,000 lb. per sq. in.

X_{41} = Size of yarn (14s, 22s, 36s, 60s)

Factors in equation--	Calculations for predicting strength of-- 14s	22s	36s	60s
Constant =	-2,939.56	-2,939.56	-2,939.56	-2,939.56
- 17.64 x 14 =	- 246.96	--	--	--
- 17.64 x 22 =	--	- 388.08	--	--
- 17.64 x 36 =	--	--	- 635.04	--
- 17.64 x 60 =	--	--	--	-1,058.40
+ 6.32 x 104 =	+ 657.28	+ 657.28	+ 657.28	+ 657.28
+ 2,126.62 x 1.08 =	+2,296.75	+2,296.75	+2,296.75	+2,296.75
+ 19.42 x 80 =	+1,553.60	+1,553.60	+1,553.60	+1,553.60
- 131.90 x 3.9 =	- 514.41	- 514.41	- 514.41	- 514.41
+ 3.53 x 84 =	+ 296.52	+ 296.52	+ 296.52	+ 296.52
+ 20.89 x 94 =	+1,963.66	+1,963.66	+1,963.66	+1,963.66
Total	+3,066.88	+2,925.76	+2,678.80	+2,255.44
$\frac{3,066.88}{14}$ =	219.1	--	--	--
$\frac{2,925.76}{22}$ =	--	133.0	--	--
$\frac{2,678.80}{36}$ =	--	--	74.4	--
$\frac{2,255.44}{60}$ =	--	--	--	37.6
Actual yarn strength, in lbs.	220.0	137.0	76.0	40.0
Difference between predicted and actual yarn strength, in lbs.	- 0.9	- 4.0	- 1.6	- 2.4
Difference between predicted and actual yarn strength, in pct.	- 0.4	- 2.9	- 2.1	- 6.0

EVALUATION OF THE RELATIONS OF THE FACTORS INCLUDED IN THE TWO NEW EQUATIONS

The degree of multiple relationships existing between the factors included in the 2 equations here reported, as based on 3,267 lots of yarn representing 842 cottons, crop years 1948-50, is shown by the statistical values listed below:

Statistical values	Analysis including	
	6 quality factors	3 fiber properties
Coefficient of correlation ($\bar{R}$)	0.907	0.896
Percentage of variance explained ($\bar{R}^2$ x 100)	82.33	80.23
Standard error of prediction ($\bar{S}$), csp units	±156.56	±165.61
Standard error of prediction ($\bar{S}$), percent	± 6.91	± 7.31

As will be noted, the two sets of corresponding statistical values shown above are very similar in magnitude whether 6 cotton-quality factors or the 3 most important fiber properties to count-strength product were used in the multiple correlation analysis. The value of 0.907 for the coefficient of correlation ($\bar{R}$) for the 3 crop years of 1948-50, however, was slightly smaller than that obtained for each of the first 2 crop years included in the over-all analysis. Referring to publication (8), it will be seen that the coefficients of correlation ($\bar{R}$) showed values with 6 cotton-quality factors in relation to count-strength product for the individual crop years as follows: 0.945 in 1948, 0.942 in 1949, and 0.904 in 1950. It does not necessarily follow, however, that the value of the correlation coefficient ($\bar{R}$) for the 3 crop years combined should equal the arithmetic mean value of the 3 separate crop years involved, as the levels, ranges, and distribution of data representing the cotton fiber properties, yarn strength, and count-strength product varied more or less in the respective analyses.

The correlation values ($\bar{R}$ and $\bar{R}^2$ x 100) shown in the previous tabulation for commercially produced cottons in 1948-50 and representing 3 dates of harvesting are somewhat smaller, and the values for their associated standard errors of estimate ($\bar{S}$) are larger, as compared with corresponding values reported in publication (18) for the 1945-47 series of cottons, 70 percent of the latter of which comprised cottons from the annual variety test series and 90 percent of which represented early season samples. The statistical values obtained with the 1945-47 cottons are shown on the following page.

Statistical values	Analysis including	
	6 quality factors	3 fiber properties
Coefficient of correlation ($\bar{R}$)	0.936	0.927
Percentage of variance explained ($\bar{R}^2$ x 100)	87.50	85.90
Standard error of prediction ($\bar{S}$), csp units	±126.00	±135.00
Standard error of prediction ($\bar{S}$), percent	± 5.80	± 6.20

The comparative statistical values obtained for the two series of cottons, representing different sets of conditions, are in general line with previous findings obtained in this series of studies. That is, better correlation values have been obtained with cottons from the annual variety test series and representing only first-picking samples than with cottons grown under commercial conditions over wide areas, harvested by mechanical and other methods, and representing three dates of harvesting.

Net effect of respective cotton-quality factors on count-strength product. The average net effect of the respective factors on count-strength product of all yarn sizes collectively for the 1948-50 series of cottons are revealed by the values of the respective beta coefficients and ranks of importance listed below:

Factors	Rank	Beta values from analysis including	
		6 quality factors 1/	3 fiber properties 1/
Yarn size	(1)	-0.693 ± 0.007	-0.691 ± 0.008
Upper half mean length	(2)	+ .387 ± .008	+ .442 ± .008
Fiber strength	(3)	+ .349 ± .008	+ .384 ± .008
Fiber fineness	(4)	- .182 ± .011	- .082 ± .008
Length uniformity ratio	(5)	+ .115 ± .008	---
Grade index	(6)	+ .086 ± .008	---
Percentage of mature fibers ..	(7)	+ .054 ± .010	---

1/ The sign indicates the direction of the contribution of the independent variable to the dependent variable.

It is of interest to note that all of the foregoing beta values are statistically significant; that is, all values are more than three times their respective standard errors. Yarn size, as naturally is to be expected, showed the largest average effect on count-strength product of all yarn sizes collectively. The three most important fiber properties to count-strength product of all yarn sizes collectively are listed in order of rank, as follows: Fiber length, fiber strength, and fiber fineness. The remaining 3 cotton-quality factors considered ranked in order of importance as follows: Fiber length uniformity, grade, and percentage of mature fibers.

It also is of interest to note that the beta values representing the average effects of upper half mean length and fiber strength toward count-strength product of all yarn sizes collectively were slightly larger when only the 3 most important fiber properties were included in the analysis than when all 6 cotton-quality factors were included. The beta value for fiber fineness, on the other hand, was slightly larger in the analysis with all cotton-quality factors. The effect of yarn size was approximately constant in both instances, as no interactions are involved with this factor as with cotton fiber properties.

Percentage contribution of the respective cotton quality factors to count-strength product. The average net contributions of the respective factors to count-strength product of all yarn sizes collectively for the 1948-50 series of cottons are shown by the percentage values listed below:

Factors	Percentage contribution to csp by	
	6 quality factors	3 fiber properties
Yarn size	48.91	46.32
Upper half mean length	15.26	18.95
Fiber strength	12.40	14.31
Fiber fineness	3.37	.65
Length uniformity ratio	1.34	---
Grade index	.75	---
Percentage of mature fibers	.30	---
Total variance in csp explained	82.33	80.23
Total variance unaccounted for	17.67	19.77
Total	100.00	100.00

The foregoing percentage values were calculated from the reported values for the beta coefficients, as follows: Square the beta values, obtain the sum of those squares, calculate the difference between that sum and the R^2 x 100 value (to reveal the amount of interactions and residuals involved), and distribute the plus or minus differences among the squared beta values in accordance with their relative magnitude.

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